Dielectric Constant Measurement of Collagen at Terahertz Band ~~with THz TDS System~~

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***Abstract*—In this paper, the cultivated collagen is measured with Terahertz Time-Domain Spectroscopy system and its optical/EM parameters are calculated at the THz band up to 2 THz. By comparing the measurement data with the previous published ones it can be concluded that the cultivated collagen is not enough to represent the performance of the epidermis at the band of interest.**

I. Introduction

Body-centric nano-communication has been a hot topic since its proposal [1], [2]. It is generally believed that the terahertz (THz) band is a promising candidate for the EM paradigm because of the characterisation of the novel materials, *i.e.*, carbon nano tube and graphene. To study the channel performance at THz band, the investigation of parameters of human body is essential. Animal tissues, such as pork skin, pork fat and rat skin, were measured to study the absorption power and far-infrared wave transmission at THz band [3]. Due to the different performance of the cancerous tissues to the healthy ones at THz band, numerous studies are conducted on the characterisation of the human tissues at such bands [4]–[6]. To enrich the database, the cultivated collagen was measured with THz TDS system and the dielectric constant of the sample was compared with the one of real skin in the open literature to see if the collagen sample could replace the real skin in the EM simulation or measurement.

The rest ~~is~~ as follows. Section II presents a brief introduction to the data-process while the measured results and discussions are conducted in Section III. In the end, a brief conclusion is drawn in the end.

II. Data Processing

The cultivated sample is contained in a plastic holder and then measured in the THz TDS system of transmission mode, where the measured transfer function is:

$$\tilde{H}_{measure}(f) = \frac{\tilde{E}_{sam}(f)}{\tilde{E}_{ref}(f)} \tag{1}$$

where, $\tilde{E}_{sam}(f)$ and $\tilde{E}_{ref}(f)$ are the complex spectra of the sample and reference, obtained from the Fourier Transform of the corresponding time-domain response.

On the other hand, the analytical transfer function can be written as:

$$\tilde{H}(f) = \tilde{t}_{12}(f)\tilde{t}_{21}(f)e^{-\frac{i2\pi f(\tilde{n}-n_{air})d}{c}} \tag{2}$$

where, f stands for the frequency; $\tilde{n}$ represents the complex refractive index; n_{air} is the refractive index of air because air is usually taken as the reference; d stands for the sample thickness; c is the free-space light speed; $\tilde{t}_{12}(f)$ and $\tilde{t}_{21}(f)$ are the Fresnel transmission coefficients associated with the front and back boundary interfaces between sample and holder medium. By comparing both transfer function, the non-linear regression algorithm is applied to get the complex refractive index.

III. Measured Results and Discussions

Fig. 1 shows the time response of air, empty holder and the holder with the sample. By using the method stated above, the refractive index and extinction coefficient can be obtained, shown in Fig. 2. It can be summarised that with the rise of the frequency the refractive index and extinction coefficient both decrease. Before $0.5\ THz$, both parameters descend steeply while after $0.5\ THz$ both parameters drop slightly.

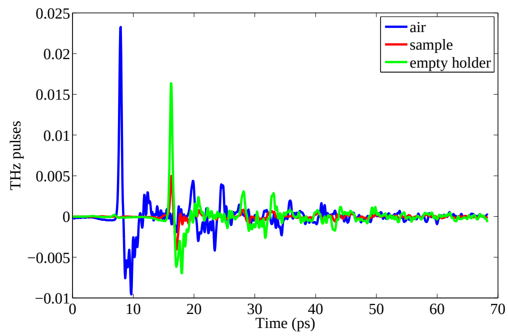
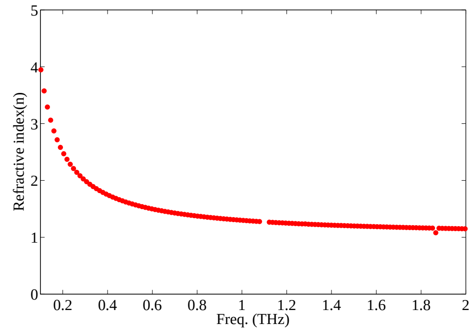


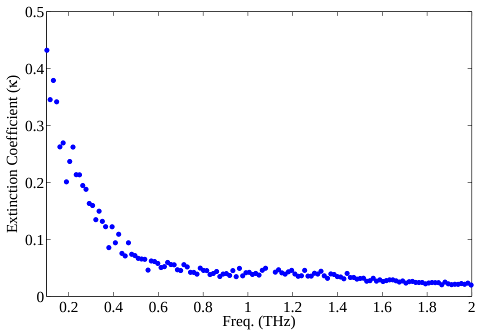
Fig. 1. Time response of air, empty holder and the holder with the sample measured by THz-TDS system

Using the following relationship between the EM parameters to the optical parameters, Eq. 3, the permittivity of the collagen can be obtained, as shown in Fig. 3. Similar to the optical parameters, the permittivity falls with the increase of the frequency and there is also a cut-off point i.e., $0.5\ THz$ approximately, where the trend of both curves change.

$$\begin{cases} \epsilon_r' = n_r(f)^2 - \kappa(f)^2 \\ \epsilon_r'' = 2n_r(f)\kappa(f) \end{cases} \tag{3}$$

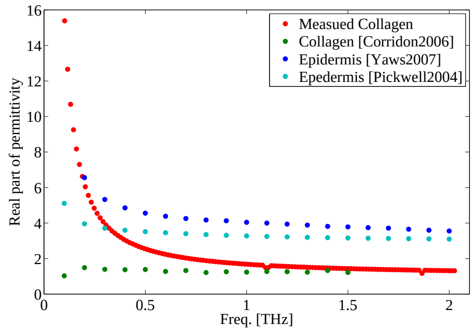


(a) Relative refractive index measured by THz-TDS system

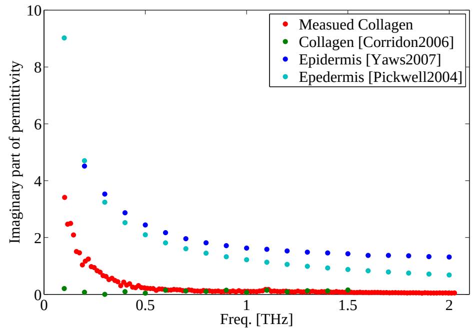


(b) Extinction coefficient measured by THz-TDS system

Fig. 2. Measured optical parameters of collagen from THz-TDS system



(a) Comparison of the real part of the dielectric constants of skin



(b) Comparison of the imaginary part of the dielectric constants of skin

Fig. 3. Comparison between the measured results with other avaiblable data from [8]–[10]

where, ϵ_r' , ϵ_r'' represent the real part and imaginary part of the relative permittivity ϵ_r.

Fig. 3 shows the comparison of the measured results with the data extracted from [8]–[10]. From the figure, it can be easily seen that the trend of the three curves are similar but the permittivity of the measured collagen is less than the others', demonstrating that the collagen is not enough to represent the epidermis at the band of interest.

IV. Conclusion

The paper investigates the possibility of the use of the collagen as the real skin by comparing the measured results to the available data. From the results, it can be seen that the cultivated collagen is not enough to represent the real whole skin at the band of interest.

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